

resilient member to be held in contact with the outer cylindrical surface of the center shaft, the annular spring member of the sealing ring operative to impart a force to the sealing lip of the annular resilient member to ensure that the sealing lip of the annular resilient member is held in tight contact with the outer cylindrical surface of the center shaft; and a second sealing unit received in the opening of the vacuum casing and fixedly supported by the base portion of the vacuum casing, the second sealing unit including a retaining member in the form of an annular ring shape and fixedly connected with the base portion of the vacuum casing, and a sealing ring in the form of an annular ring shape and securely retained by the retaining member of the second sealing unit, the sealing ring of the second sealing unit intervening between the retaining member of the first sealing unit and the retaining member of the second sealing unit to hermetically seal the gap between the retaining member of the first sealing unit and the retaining member of the second sealing unit, the sealing ring of the second sealing unit including an annular resilient member formed with an annular groove, and an annular spring member received in the annular groove of the annular resilient member and retained by the annular resilient member, the annular resilient member of the sealing ring having a peripheral portion securely retained by the retaining member, and a sealing lip integrally formed with the peripheral portion of the annular resilient member and radially inwardly extending from the peripheral portion of the annular resilient member to be held in contact with the outer cylindrical surface of the first sealing unit, the annular spring member of the sealing ring operative to impart a force to the sealing lip of the annular resilient member to ensure that the sealing lip of the annular resilient member is held in tight contact with the outer cylindrical surface of the first sealing unit.

In accordance with a fourth aspect of the present invention, there is provided a shaft sealing apparatus, comprising: a vacuum casing formed with a vacuum chamber and having a base portion formed with an opening to have the vacuum chamber of the vacuum casing held in communication with the atmosphere through the opening of the vacuum casing; a shaft housing in the form of a cylindrical hollow shape and fixedly connected with the base portion of the vacuum casing, the shaft housing having an inner cylindrical surface; a sleeve shaft in the form of a cylindrical hollow shape and received in the shaft housing to be movably supported by the shaft housing, the sleeve shaft held in coaxial alignment with the shaft housing and having a first axial end extending in the vacuum chamber of the vacuum casing, a second axial end extending in the atmosphere, an outer cylindrical surface smaller in diameter than the inner cylindrical surface of the shaft housing, and an inner cylindrical surface; a center shaft in the form of a cylindrical shape and received in the sleeve

shaft to be movably supported by the sleeve shaft, the center shaft held in coaxial alignment with the sleeve shaft and having a first axial end extending in the vacuum chamber of the vacuum casing, a second axial end extending in the atmosphere, and an outer cylindrical surface smaller in diameter than the inner cylindrical surface of the sleeve shaft; a first sealing unit fixedly supported by the sleeve shaft, the first sealing unit including a retaining member in the form of an annular ring shape and fixedly supported by the sleeve shaft, and a sealing ring in the form of an annular ring shape and securely retained by the retaining member of the first sealing unit, the sealing ring of the first sealing unit intervening between the center shaft and the retaining member of the first sealing unit to hermetically seal the gap between the center shaft and the retaining member of the first sealing unit, the sealing ring of the first sealing unit including an annular resilient member formed with an annular groove, and an annular spring member received in the annular groove of the annular resilient member and retained by the annular resilient member, the annular resilient member of the sealing ring having a peripheral portion securely retained by the retaining member, and a sealing lip integrally formed with the peripheral portion of the annular resilient member and radially inwardly extending from the peripheral portion of the annular resilient member to be held in contact with the outer cylindrical surface of the center shaft, the annular spring member of the sealing ring operative to impart a force to the sealing lip of the annular resilient member to ensure that the sealing lip of the annular resilient member is held in tight contact with the outer cylindrical surface of the center shaft; and a second sealing unit fixedly supported by the base portion of the vacuum casing, the second sealing unit including a retaining member in the form of an annular ring shape and fixedly supported by the base portion of the vacuum casing, and a sealing ring in the form of an annular ring shape and securely retained by the retaining member of the second sealing unit, the sealing ring of the second sealing unit intervening between the sleeve shaft and the retaining member of the second sealing unit to hermetically seal the gap between the sleeve shaft and the retaining member of the second sealing unit, the sealing ring of the second sealing unit including an annular resilient member formed with an annular groove, and an annular spring member received in the annular groove of the annular resilient member and retained by the annular resilient member, the annular resilient member of the sealing ring having a peripheral portion securely retained by the retaining member, and a sealing lip integrally formed with the peripheral portion of the annular resilient member and radially inwardly extending from the peripheral portion of the annular resilient member to be held in contact with the outer cylindrical surface of the sleeve shaft, the annular spring member of the sealing ring operative to impart a force to the sealing lip

of the annular resilient member to ensure that the sealing lip of the annular resilient member is held in tight contact with the outer cylindrical surface of the sleeve shaft.

The shaft sealing apparatus may further comprise a first labyrinth seal unit intervening between the sleeve shaft and the center shaft to be exposed to the vacuum chamber of the vacuum casing, and a second labyrinth seal unit intervening between the vacuum casing and the sleeve shaft to be exposed to the vacuum chamber of the vacuum casing, the first labyrinth seal unit including an outer ring member provided on the first axial end of the sleeve shaft, and an inner ring member provided on the first axial end of the center shaft, the outer and inner ring members of the first labyrinth seal unit collectively forming an interstice therebetween, the second labyrinth seal unit including an outer ring member provided on the base portion of the vacuum casing, and an inner ring member provided on the first axial end of the sleeve shaft, the outer and inner ring members of the second labyrinth seal unit collectively forming an interstice therebetween.

The shaft sealing apparatus may further comprise a base member in the form of a circular shape and provided on the first axial end of the center shaft, a first fixed member in the form of an annular ring shape and provided on the first axial end of the sleeve shaft, and a second fixed member in the form of an annular ring shape and provided on the base portion of the vacuum casing, the base member and the first fixed member collectively constituting the first labyrinth seal unit, the first and second fixed members collectively constituting the second labyrinth seal unit.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of a shaft sealing apparatus according to the present invention will more clearly be understood from the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a fragmentary cross-sectional view of a first embodiment of the shaft sealing apparatus according to the present invention;

FIG. 2 is an enlarged cross-sectional view of a sealing ring forming part of the shaft sealing apparatus shown in FIG. 1;

FIG. 3 is an enlarged cross-sectional view similar to FIG. 2 but showing another type of sealing ring forming part of the shaft sealing apparatus shown in FIG. 1;

FIG. 4 is a fragmentary cross-sectional view similar to FIG. 1 but showing a preparing step performed by the shaft sealing apparatus shown in FIG. 1;

FIG. 5 is a fragmentary cross-sectional view similar to FIG. 4 but showing first and second installing steps performed by the shaft sealing apparatus shown in